

## BOOK REVIEWS

GESTEINE UND MINERALLAGERSTÄTTEN. Vol. I, Allgemeine Lehre von den Gesteinen und Minerallagerstätten, by PAUL NIGGLI, with special assistance on Part IV by ERNST NIGGLI.

This prodigious effort in the field of geological monographs is but the initial work of a three volume series which is rapidly nearing completion. The manuscript for Volume II, "Die exogenen Gesteine und Minerallagerstätten", is already complete, and Volume III, "Die endogenen Gesteine und Minerallagerstätten", is now in preparation. The book is published by the Verlag Birkhäuser of Basel, Switzerland, as number 3 of their "Textbooks and Monographs in the Provinces of the Exact Sciences, Mineralogical-Geotechnical Series." Bound copies sell for 46 Swiss francs.

The fundamental concept of Volume I is expressed by Professor Niggli in the introduction where he states (in translation), "The majority of similar works are subdivided at a very early stage into sediments, igneous rocks, and metamorphic rocks; the exposition of the fundamental principles commands only very little space. Since, in the opinion of the author, this early splitting of and development of separate concepts as well as a frequently encountered lack of preliminary information about the associated sciences have worked out unfavorably, an attempt at a new type of presentation had to be undertaken." Indeed, the presentation is unorthodox for a book that purports to consider rocks and mineral deposits.

The work describes neither rocks nor mineral deposits, but concerns itself with constructing a framework of pertinent principles in geochemistry, crystal chemistry, physical chemistry, and geophysics. Part I, which deals with the material foundation, i.e., the nature of the constituents, considers the general chemistry of rocks, and the geochemical rules that govern the distribution of elements in the earth. This leads to a discussion of the formation of radicals and molecules and the nature of the crystalline state. About 30 pages is devoted to a brief description of "the most important minerals." Formulae of the silicate minerals are expressed so that the coordination relationships of the atoms can be read. Thus the formula for albite,  $[(\text{SiO}_4/2)_3(\text{AlO}_4/2)]\text{Na}$ , indicates a structure in which two tetrahedra connect at each corner of a silicate tetrahedron (i.e., one doubly-coordinated O atom occurs with three doubly coordinated O atoms), in which one-fourth of the Si positions are occupied by Al, and in which Na represents the cation element occupying the relatively large spaces between the tetrahedra. This scheme of representation will no doubt confuse those geologists who are not readily conversant with crystallographic notation.

Part II considers the spatial relationships between the constituents of rocks and mineral deposits, i.e., textures and structures. Space is also devoted to a discussion of the application of statistics to petrologic problems and to a section on methods of determining and representing the quantitative mineralogical composition of rocks. Grain sizes, grain shapes, inter-growths, overgrowths, aggregate forms, orientation, porosity, and permeability—all are treated from a fundamental viewpoint so as to provide a basis for interpretation of all types of mineral aggregates.

In Part III Professor Niggli is concerned with the physical chemistry of mineral deposits and of their formation. Subdivisions here include a treatment of the laws governing the stability and coexistence of minerals in combination, under which heterogeneity, equilibrium, the phase rule, and poly-component systems are discussed, and a section dealing with significant processes in the formation of minerals.

Ernst Niggli, in Part IV, develops fundamental geophysical concepts of the earth. Also, data are listed on temperature, pressure, viscosity, and elasticity. A section on applied geophysics describes methods for the delineation of geological structures and the discovery of

mineral deposits, including gravimetric, seismic, electrical, electromagnetic, magnetic, radioactive, geothermal, and geochemical methods.

The final part deals with the fundamentals of classification of rocks and mineral deposits. The processes of mineral formation are listed as twofold: (1) those that function in the border zones of the lithosphere, atmosphere, and hydrosphere, and (2) those that are completed within the lithosphere. Rocks and mineral deposits resulting from the first set of processes are termed exogenic; those owing their origin to the second group are called endogenic. Under the first are included (1) the autochthonous rocks and deposits formed by weathering and (2) the sediments. The subdivisions of sediments are (a) clastic sedimentary rocks, (b) pelites, gelites, humites, and related rocks, (c) carbonate rocks, (d) sulfate, and chloride rocks, etc., and (e) snow and ice. The endogenic rocks are no longer first classified under the primary headings of magmatic and metamorphic but according to the intensity conditions of their formation. Niggli recognizes three intensity zones: the kathermal zone whose upper temperature limit is that of crystallizing igneous rocks, the epithermal zone whose lower temperature limits approach those normally prevailing on the surface of the earth, and the zone intermediate between these two, or mesothermal.

These three are grouped into two general divisions, (1) kathermal rocks and mineral deposits and (2) epi- to mesothermal rocks and mineral deposits. Group one includes most of the igneous rocks, including pegmatites, high temperature vein materials, as well as ortho- and paragneisses, and migmatites and (kata)diabrochites (rocks resulting from strong high-temperature hydrothermal and pneumatolytic alteration). In group two are placed the bulk of the metamorphic rocks (schists, quartzites, marbles, tactites, etc.) and low-temperature vein materials. The volume concludes with a valuable list of pertinent books and a very good index.

Without doubt this work represents one of the most significant contributions to mineralogy that has ever been published. In a brief review it is impossible to present adequately the tremendous scope of the book and to sample the wealth of detailed information that it pours forth in its 540 pages, 335 uniformly excellent illustrations, and 43 concentrated tables. The greatest value of the work is that it presents on a unified basis the fundamental principles and concepts ordinarily scattered through books on crystallography, crystal chemistry, mineralogy, petrology, petrography, metamorphism, geophysics, and economic geology. It is, in fact, a monograph on paragenetic mineralogy which considers the formation of rocks and mineral deposits from the threefold viewpoint of composition, spatial relationships, and genesis. In the minds of the average beginning or intermediate students it will probably result in much mental indigestion; but it will prove rich fare for advanced mineralogical and geological personnel.

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FOURIER TRANSFORMS AND STRUCTURE FACTORS. By DOROTHY WRINCH.  
ASXRED MONOGRAPH NUMBER 2, (1946).

The science of  $x$ -ray crystallography depends upon the fact that matter scatters  $x$ -rays in a manner dependent upon the arrangement of extra-nuclear electrons in the scatterer. Given any arrangement of scattering matter, and the wave-length, incident direction and intensity of an  $x$ -ray beam, it is possible to calculate in a straight-forward manner the electric vector and the intensity of scattered radiation at any point in space surrounding the scatterer. The aim of structure analysis is to solve the converse problem: given the intensity of scattered  $x$ -rays in a region surrounding a scattering body, and given the incident beam direction, wave-length, and perhaps the incident intensity, what is the distribution of electrons responsible for the pattern of scattered radiation?

It is well known that this question is not answerable in a general way, since one can ob-

serve only the amplitudes of the scattered electric vectors but *not* their phases. Nevertheless, auxiliary information of a chemical or physical nature is sometimes available which permits deduction of the required phases; or these may be established by trial-and-error methods.

The relationship between the density of scattering material, expressed as a function of position, and the scattered electric vectors—also expressed as a function of position in surrounding space (this latter function being called the structure factor), can be presented in a manner which brings out the functional interdependence very beautifully and which facilitates mathematical transformation from one to the other in such a way as to give great insight into the influence of one function upon the other. Specifically, by proper choice of coordinate systems these two functions become the Fourier transforms of one another.

It is with some aspects of this relationship of the density-function and structure-factor as Fourier mates that the little volume by Dr. Dorothy Wrinch, *Fourier Transforms and Structure Factors*, is concerned. This work is the second in a series of monographs published under the auspices of the American Society for X-Ray and Electron Diffraction.

The purposes of Dr. Wrinch's work, as stated in her Preface, are: firstly, the study of the structure factors of certain atomic groupings of frequent occurrence in both inorganic and organic crystals; and secondly, an introduction to "the language of structure factors" as "a necessary preliminary to the interpretation of the intensity maps of crystals made up of megamolecules of unknown structure." Of the second aim, nothing more is said anywhere in the volume. In chapter 1 the Fourier transform relationships between a density function and its structure factor are outlined. Chapter 2 discusses the general influence of the positions and symmetry of distributions upon the nature of their transforms. These are expansions of concepts of Hettich,<sup>1</sup> Patterson,<sup>2</sup> Ewald<sup>3</sup> and others, to whom the Fourier transform viewpoint is originally due. Both of these chapters are of prime importance.

The remaining sections of the monograph are concerned with transforms of specific distributions. Chapters 3, 4 and 5 deal with transforms of sets of points, computations being carried out for equi-weighted points at the vertices of cubes, tetrahedra, and octahedra, in trigonal and hexagonal meshes, and within surfaces and volumes of certain figures. Chapter 6 is an extension of the preceding material to certain continuous distributions. Chapter 7 is a discussion of some effects of crystal shape and size.

The monograph contains much excellent material, succinctly written. It is a contribution to the theory of  $x$ -ray scattering which should be read by every investigator seeking for a fuller understanding of the relations between density distributions and scattering patterns. Nevertheless, the work leaves much to be desired. The full strength of the transform method is obscured when so large a part of a discussion of it is devoted to computations of transforms of special equi-weighted point sets. In this first extended discussion of the viewpoint it is disappointing to find so little background material in  $x$ -ray scattering and such absence of comparison between the Fourier integral treatment and the more commonly used analytical methods. There is a dearth of discussion of the contributions of previous investigators of the transform methods, and no reference is made to some of the most important earlier papers—among these, for example, the short but important review by Ewald<sup>3</sup> which appeared six years previously. The effects of space-group symmetry in the

<sup>1</sup> Hettich, A., Beitrage zur Methodik der Strukturbestimmung: *Zeit. Krist.*, **90**, 483 (1935).

<sup>2</sup> Patterson, A. L., The diffraction of  $x$ -rays by small crystalline particles: *Phys. Rev.*, **56**, 972 (1939). See also earlier papers.

<sup>3</sup> Ewald, P. P., X-ray diffraction by finite and imperfect crystal lattices: *Proc. Phys. Soc.*, **52**, 167 (1940).

development of the transform of an entire unit cell from the transform of the "asymmetric motif" of the cell, as touched upon by Hettich<sup>1</sup> or Knott,<sup>4</sup> are not discussed in the monograph, although they are straightforward and among the most important applications of theorems concerning the influences of rotations and translations of a function upon its transform. No use of—and indeed no reference to—convolution theorems is made in the monograph, despite the elegance which these lend to the mathematical theory, and the deeper insight which they provide into its application in *x-ray* scattering problems. No discussion appears of such matters of practical importance as the relations between the *transform of a given function* and the *transform of that function sampled periodically with varying degrees of fineness*.

Despite the incompleteness of her monograph—and it must be recognized that we are warned of some of these in her Preface—structural crystallographers owe Dr. Wrinch a debt of gratitude for focussing their attention once again upon Fourier transform methods. Those who have not read her volume owe it to themselves to do so.

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<sup>4</sup> Knott, G., Molecular structure factors and, their application to the solution of the structures of complex organic crystals: *Proc. Phys. Soc. Lond.*, **52**, 229 (1940).